Institution: University of Kent

Unit of Assessment: 11: Computer Science and Informatics

Title of case study: Greenfoot: Transforming Student Learning and Pedagogical Innovativeness in Programming Internationally

Period when the underpinning research was undertaken: 2005-2017

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Michael Kölling	Professor	2005-2017
Ian Utting	Senior Lecturer	1982-2020
Poul Henriksen	Research Associate	2005-2009
Neil Brown	Research Associate	2009-2017
Davin McCall	Research Associate	2011-2017

Period when the claimed impact occurred: August 2013-2020

Is this case study continued from a case study submitted in 2014? Yes

1. Summary of the impact (indicative maximum 100 words)

Pedagogical and technical research in computer science at Kent led to the development of Greenfoot – a unique software system that supports the learning of programming at school level (age 13+). Greenfoot has generated reach in 49 countries, been translated into 12 languages, and, since August 2013, has improved the learning of programming for more than 3.9 million schoolchildren and supported the teaching capacity and innovativeness of over 5,000 teachers. Additionally, Greenfoot has been used by Computing at School (CAS) and the Welsh Joint Education Committee (WJEC) to develop and improve the provision of computer science through the national curriculum, and employed by key stakeholders, such as Oracle and Technocamps, to advance the profiling of programming and drive knowledge. For instance, the Oracle Academy Greenfoot curriculum was studied by thousands of students in over 70 countries in 2020.

2. Underpinning research (indicative maximum 500 words)

Background

Traditional approaches to programming education used to rely on text-based development environments designed mainly for professional programmers. From a student-pedagogical perspective, these environments are difficult to use, hard to interact with, and force learners through large amounts of detail before enabling them to achieve the first motivating impact. Using such programmes in secondary/high-school education settings, therefore, leads to problems in comprehension, engagement, and motivation among the students; they become resistant to learning programming despite software usage and understanding of its fundamentals being an ever more important, ingrained skill set applied in society. Similarly, teachers also found the text-based programming environments problematic for delivering modern programming paradigms in an innovative and engaging way. Responding to these issues, from **2005** to **2017** a Kent project team led by led by Kölling, and comprising Utting, Brown, Henriksen, and McCall, developed Greenfoot – an integrated development environment that allows easy conception of two-dimensional graphic applications – along with other supporting, instructional user websites and easy-to-use material.

Research and its pathways to impact

The Greenfoot project developed from two strands – pedagogical research and technical computer science research. The project provided an introduction to the different elements of the ecosystem (community, discussion, availability of material), along with the conception of the Greenfoot textbook **[R6]**. The Kent project group carried out research in both areas, including research in the development of new interaction techniques to support the learning

of programming; the design and implementation of the software; and, the usability and effectiveness of the resulting system.

In **2005**, the initial phase of pedagogical research and system design was led by Kolling and carried out jointly with Henriksen and John Rosenberg and Bruce Quig from La Trobe University. Then, in **2007**, members of the Kent group (Brown, Kölling, McCall, Utting) made original contributions to Human Computer Interaction (HCI) in the context of novice programming systems, introducing interaction techniques that allow more experimentation and exploration, accelerate feedback, and, through this, increase engagement and motivation. This later work enabled the inception of new learning approaches that invert traditional curricula, such as allowing discussion of high-level 'advanced' concepts before discussion of syntax. With regard to programming environment technology, the research identified novel interaction techniques that enable a more direct and experimental approach to interacting with a programming system. Collectively, both aspects of this pedagogical strand of research were based on constructivist learning theories, which were specialised to the initial learning of programming, and, specifically, to the learning and teaching of concepts of object orientation. As a result, the understanding of key requirements to support initial learning of programming led to the formulation of goals and targets for system characteristics, such as interactivity, visualisation, and support for self-directed experimentation, thus making original contributions to computing pedagogy **[R1, R2]**.

The second strand of the research was concerned with developing computer system abstractions and interaction techniques to realise the system characteristic goals in the context of a modern, statically typed, object-oriented language (Java, in this instance). Some of the techniques integrated into Greenfoot were modified from earlier highly interactive programming systems, such as Smalltalk and Self, and were adapted to the statically typed nature of Java. Specifically, the Kent group developed a new conceptual framework of object-oriented programming concepts and concrete novel interaction techniques **[R3]**. Then, in **2010**, further research identified that the ecosystem has a major influence on learning success and the team sought to expand this by creating a community and social support for learning. As such, the Kent group created a technology-supported online community around Greenfoot, including the development of novel social interaction models, combining aspects of resource repositories **[R2]** and social networks **[R4, R5]**.

3. References to the research (indicative maximum of six references)

[R1] **Kölling, Michael** and **Henriksen, Poul** (**2005**). 'Game Programming in Introductory Courses with Direct State Manipulation'. *In: ITiCSE 2005: Proceedings of the 10th annual SIGCSE conference on Innovation and Technology in Computer Science Education*. ACM Press, New York, New York (USA), pp. 59-63. ISBN 1-59593-024-8. https://dx.doi.org/10.1145/1067445.1067465. http://kar.kent.ac.uk/14304/

[R2] Fincher, Sally and **Kölling, Michael** and **Utting, Ian** and **Brown, Neil C.C.** and Stevens, Phil (**2010**). 'Repositories of teaching material and communities of use: nifty assignments and the greenroom'. In: *Proceedings of the Sixth international workshop on Computing education research*. https://doi.org/10.1145/1839594.1839613. http://kar.kent.ac.uk/30638/

[R3] **Kölling, Michael** (**2010**). 'The Greenfoot Programming Environment'. *ACM Transactions on Computing Education (TOCE)*, 10(4):1-21. ISSN 1946-6226. https://doi.org/10.1145/1868358.1868361. http://kar.kent.ac.uk/30614/

[R4] **Henriksen, Poul** and **Kölling, Michael** and **McCall, Davin** (**2010**). 'Motivating programmers via an online community'. *J. of Computing Sciences in Colleges*, 25(3): 182-196. ISSN 1937-4771. https://dl.acm.org/doi/abs/10.5555/1629116.1629132. http://kar.kent.ac.uk/30701/

[R5] **Brown, Neil C.C.** and **Kölling, Michael** (**2013**). 'A Tale of Three Sites: Resource and Knowledge Sharing Amongst Computer Science Educators'. *In: Ninth Annual International Computing Education Research Conference (ICER)*, Aug 2013, San

Diego, USA, pp. 27-34. https://doi.org/10.1145/2493394.2493398. http://kar.kent.ac.uk/37642/

[R6] **Kölling, Michael** (**2016**). *Introduction to Programming with Greenfoot: Object-Oriented Programming in Java with Games and Simulations*, Second edition, Pearson. ISBN-10: 013-405429-6, ISBN-13: 978-013-405429-2. https://www.greenfoot.org/book/

Grants

The research was supported by a series of American industry grants over a period of several years, including: $650,000 from SUN Microsystems (2005-2008), $450,000 SUN foundation (2009-2010), $2m from Oracle Corp (2011-2017) and $36,000 from Google (2011-2013), totaling more than US$3.1 million.

4. Details of the impact (indicative maximum 750 words)

Greenfoot is supported by its own channel on YouTube with instructional videos (4,850 subscribers and over 1 million views) **[a]** and two supporting websites, one for its end users, the students (40,000 subscribers and 200,000 page views per month) **[b]** and one for teachers entitled the 'Greenroom' (5,419 subscribers, 241 resources and 4,114 discussion posts) **[c]**. Greenfoot has been adopted in over 49 countries **[d]**, the user interface translated into 13 languages (including Chinese, Portuguese, German, and Spanish), and the Greenfoot tutorials translated into seven languages (Brazilian, German, Greek, Indonesian, Italian, Russian and Spanish) – with all translations produced by volunteers **[b]**.

Subsequently, the international proliferation of Greenfoot across the computer science education community has generated diverse forms of pedagogical impact. Since **August 2013**, the software has improved the learning of programming and benefitted more than 3.9 million school students directly **[d, e, Fig. 1]**; enhanced the teaching capacity of over 5,000 teachers who have used it to improve how they teach programming innovatively **[c, e]**; influenced national curriculum design in the UK; and, informed the practices, philanthropic missions, and opportunities of key computer science stakeholder groups, including CAS, WJEC, Oracle and Technocamps **[f, g, h, i]**.

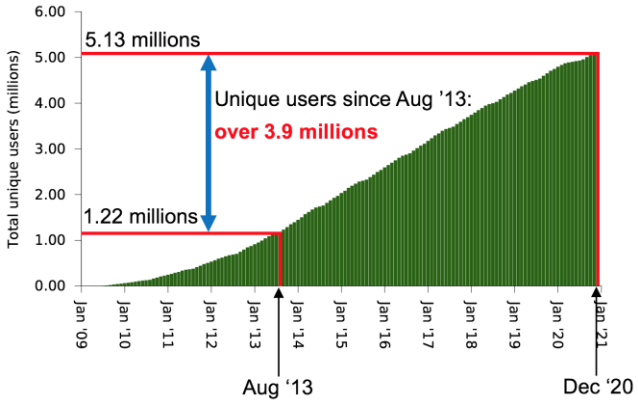

Fig. 1: Total unique users of Greenfoot (from [d])

Improving student learning and engagement internationally

Unlike the traditional programming platforms used in schools, the usability and accessibility of Greenfoot enables students to achieve more tangible results more quickly, and, through the increased motivation and satisfaction that this fosters, enhances students' understanding of programming concepts. In commenting on how Greenfoot increased learners' motivation and engagement, a teacher from Sutton Grammar School (UK) highlighted that 'My pupil was never a good student until I taught him Greenfoot. He got so inspired that he asked his parents to buy him the book, read the whole thing, and shot up to the very top of the year group in my subject with exam scores averaging 90%. He will be in my GCSE course next year, and I could not be more proud!' **[e]**. Similarly, a teacher from the Jesuit High School in Oregon (USA) noted: 'This amazing program motivates my students to learn object-oriented programming, including inheritance, interfaces, and the use of list and array structures, in an engaging and very fun manner' **[e]**.

Additionally, as pointed out by other teachers from across the USA and Germany, Greenfoot also boosts creativity and discovery in student learning: 'My students love developing games and discovering the true creativity that is required to design and develop fun and interesting software' and 'My pupils can be as creative as they want' **[e]**. Such increased motivation and creativity nurtures greater enthusiasm in the subject of Computer Science, as another UK

teacher contends: 'I get more enthusiasm teaching Greenfoot than any other aspect of teaching from year 7 to year 13. I believe that the reason my GCSE programme is so popular is due to what we teach in year 9. Out of 135 students in a year group, 63 have opted for Computer Science next year' **[e]**.

Enhancing teaching capacity and pedagogy innovativeness

Greenfoot **[b]**, its supporting textbook (16,000 copies sold) **[R6]**, and the Greenroom (the aforementioned teachers' community and support site) **[c]** also improve programming teaching practice and capacity. In contrast to the disengaging environments and language of traditional methods, Greenfoot enables teachers to teach software development principles and object orientation in a modern, graphical context. As a teacher from Vincent-Lübeck-Gymnasium (Germany) observes: 'The pedagogy behind the development environment has continuously been improved over time and on occasions made massive jumps forward. I can produce all my teaching tools inside Greenfoot [and] hence encourage the pupil to dissect my project structures and code' **[e]**. Further to increasing innovation in programming pedagogy, teachers note that their job satisfaction and ability to teach inspirationally is improved through using Greenfoot, as a teacher from Carl-Helbing-Schule Emmendingen (Germany) testifies: 'I often experience situations when the lesson is over, but some students still stay on longer, creating their games. Is there anything more satisfying an educator can dream of? The concepts of object-oriented programming become so much more clear and understandable for the students. It makes teaching concepts of OOP absolutely effortless' **[e]**. Comparably, beyond the Greenfoot site itself and in the context of the Greenroom, teachers remark on how the supporting material and community sites enhance their ability to use Greenfoot and connect with other teachers. This point is made by a teacher from Ann Arbor Huron High School in Michigan (USA): 'The nicest feature of it, beyond ease of use, is that there is a textbook that is built around the program! I have benefited from BOTH the blueroom and greenroom discussion boards. Getting lessons, questions answered, etc. The support for the product has been nice!' **[e]**. This view is echoed by the teacher from Vincent-Lübeck-Gymnasium (Germany): 'Being able to exchange knowledge with a global community of people who use Greenfoot in radically different environments is a huge help' **[e]**.

Informing UK computer science curricula

Since 2008, Computing at School (CAS) has collaborated with the Greenfoot team to accomplish its mission of promoting the teaching of computing at school across all school phases and supporting computing teachers with training and resources. Greenfoot is applied within several courses they run for teachers and since **2013** 'has been an integral part of the Welsh Joint Education Committee (WJEC) GCSE curriculum' **[f]**. The latter was part of the qualifications and reform programmes in England and Wales which saw the WJEC – a Welsh exam board – develop a new GCSE computer science qualification of which Greenfoot forms a part. In commenting on the benefits of Greenfoot's integration into the GCSE, the WJEC highlight that the software 'is used to develop an understanding of object orientated Programming using Java such that students can understand […] the concepts of inheritance and encapsulation' **[g]**. The WJEC 'value the use of Greenfoot as a component of the WJEC GCSE computer science qualifications, and the Greenfoot materials provide valuable resources for teaching' **[g]**.

In the same vein, the Vice-Chair of CAS also highlights that 'across the last decade of computing resurging in UK schools, Greenfoot has contributed to the teaching of programming in school' and 'evolved to have a special place with pupils at KS4 and A level' **[f]**. CAS testifies that 'access to the innovative software encourages pupils to program: not only enhancing their interest in programming, but also enriching their understanding of computer science. The software provides an easily-understood interactive user interface, thus lowering the entry barrier to writing and understanding code, and has an active, supportive, worldwide community, tutorials, and teaching plans' **[f]**. Correspondingly, for teachers 'it has advanced the knowledge, skills and understanding of those teaching in the classroom' **[f]**. CAS remarks in particular upon the innovativeness of Greenfoot in improving learning and teaching practice, asserting that 'the pedagogical appeal and significance of Greenfoot in advancing the

knowledge of and accessibility to computing is felt by both teachers and pupils; its technology has advanced the learning of staff and students in diverse ways' **[f]**.

Contributing to computer science philanthropy and NGO engagement initiatives

Oracle is an American multinational computer technology corporation headquartered in California that sells database software and technology, cloud-engineered systems, and enterprise software products. Since **2013** – as part of Oracle's philanthropic mission to provide a wide range of free resources and works with institutions, educations and partners across the globe via their Oracle Academy education suite – Greenfoot 'has been an important part of Oracle's Academy's curriculum' **[h].** As the Vice-President of Oracle confirms: 'In the **2020** academic year to date, Oracle Academy Greenfoot related curriculum has been studied by thousands of students in over 70 countries' **[h]**. Greenfoot, they argue, along with BlueJ and Stride, 'collectively have the potential to bring programming to every student – not just those who aim for a career in software development or computer science' **[h]**.

Technocamps is a non-profit organisation started in 2003 with a mission to inspire, motivate, and engage people with computational thinking and promote Computer Science as underpinning all aspects of modern society. Technocamps have delivered more than 2,500 workshops to over 60,000 young people across Wales on programming, games development, and much more, and Greenfoot has been included as part of their workshop curricula. The Director of Technocamps states that: 'in 2012 we developed our own workshop based on the Greenfoot material, and the reach of this workshop has increased substantially since **2013**. Our Greenfoot workshop has been delivered to approximately 3,500 pupils over the past seven years across Wales, with 125 teachers undertaking CPD courses which include Greenfoot' **[i]**. The workshop they go on and the interaction with the Greenfoot platform have 'proven to be popular and valuable in influencing teaching pedagogy and student understanding […] Feedback from the teachers has suggested that the workshops are very beneficial for improving student learning and helped the teachers to guide their pupils through the GCSE' **[i]**. Technocamps state that they have: 'benefitted greatly from the Greenfoot software in supporting teachers and other classroom practitioners to deliver workshops on digital education and programming to young people in Wales' **[i]**.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[a] Greenfoot YouTube channel, providing video tutorial and samples for using Greenfoot. http://www.youtube.com/user/18km

[b] The official home page of Greenfoot: https://www.greenfoot.org/home/

[c] The Greenroom community site for teachers using the Greenfoot software. To see map of subscribers in 50+ countries, log in with guest@example.com / guestpassword. https://greenroom.greenfoot.org/

[d] Greenfoot user statistics (as of 16 December 2020). https://bluej.org/newstats/

[e] Survey from Greenroom members (conducted between 21 June and 15 July 2019), with key statements and testimonials from teachers compiled into a report available online at: https://stewardship.atavist.com/bluej-greenfoot-report#chapter-5184004

[f] Letter from Vice-Chair of Computing At School (CAS), describing Greenfoot's continued contribution to the teaching of programming in school, and the benefits Greenfoot brings to teachers and pupils (14 October 2020).

[g] Letter from WJEC Subject Officer Computer Science with ICT, describing how Greenfoot influences the specification of the WJEC GCSE computer science qualifications (6 November 2020).

[h] Letter from the Vice-President of Oracle, describing Greenfoot's contribution to preparing those who aim for a career in software development or computer science (4 December 2020).

[i] Letter from the Director of Technocamps, describing how Greenfoot contributes to the digital and programming education of young people in Wales (21 October 2020).